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Cowpea Yield Response to Light Reflected from Different Colored Mulches

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ABSTRACT

The spectral balance (quality) of canopy light, which influences plant growth and development, may be altered by colored mulches. Field studies were conducted to evaluate the influence of mulch surface color on spectral composition of canopy light and the effect of these changes on pod yield of 'Colossus' and 'Mississippi Silver' cowpea [*Vigna unguiculata* (L.) Walp.]. Cowpea was grown on a Norfolk loamy sand (fine-loamy, siliceous, thermic Typic Kandiudult) and mulched with red, white, and black surface-colored mulches for four site-years. The far-red (FR) to red (R) photo ratios of reflected light were expressed relative to the FR/R ratio in incoming sunlight, which was assigned a value of 1.00 at the time of measurement. The FR/R ratios of light reflected from the various colored surfaces were stable relative to sunlight during the study periods; light reflected from black and white mulch surfaces had mean FR/R ratios of 1.05 ± 0.05. Red mulches reflected light with mean FR/R ratios of 1.25 ± 0.05. White, red, and black surfaces reflected > 35, 12, and 3% of the incoming photosynthetic photon flux density (PPFD), respectively. Mean daily soil temperatures at 20 mm varied <1 °C among treatments. The cultivar and the color × cultivar treatment effects were not significant. Cowpea grown over red, white, and black mulches had 4-site-yr means of 6.74, 6.32, and 6.02 Mg ha^{-1}, respectively; the red treatment mean was significantly higher (P = 0.08). It was concluded that the FR/R ratio in light reflected from mulch surfaces can influence yield of cowpea.

THE BALANCE of FR to R photons in light acts through phytochrome and influences the distribution of photosynthate within plants such as soybean [*Glycine max* (L.) Merr.] and wheat (*Triticum aestivum* L.) (Kasperbauer and Karlen, 1986; Kasperbauer, 1987, 1988). Plants irradiated with R light partitioned more photosynthate into the roots; plants irradiated with FR light partitioned more photosynthate into the shoots. The FR/R photon ratio also influences the development of the photosynthetic apparatus (Kasperbauer and Hamilton, 1984; Bradburne et al., 1989). Tobacco (*Nicotiana tabacum* L.) plants that received brief irradiation with FR light to provide a higher FR/R ratio at the end of the daily photosynthetic period had higher photosynthetic rates per unit of chlorophyll and per mass of leaf than plants that received similar irradiation with R. Additionally, the auto-regulatory mechanism for soybean nodulation has been shown to be influenced by the FR/R ratio of light (Hunt et al., 1987).

The spectral balance of canopy light can be influenced by cultural and management practices. The FR/R ratio of north/south-oriented soybean rows has been shown to be higher than that of east/west-oriented rows (Kasperbauer et al., 1984; Kasperbauer, 1987). Hunt et al. (1990) reported that soybean nodulation differences associated with row orientation were related to differences in the spectral balance of canopy light. Kaul and Kasperbauer (1988) reported that higher yields of bush bean (*Phaseolus vulgaris* L.)

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with north/south-oriented rows were due to a higher FR/R ratio in the canopy light. Row width also has been shown to influence the FR/R ratio and the seed/straw biomass ratio of wheat and soybean (Kasperbauer and Karlen, 1986; Kasperbauer, 1987).

Reflectors and mulches have been used to increase the quantity of canopy light, increase or decrease soil temperature, and conserve soil moisture (Pendleton et al., 1967; Dufault and Wiggans, 1981; Schalk and Robbins, 1987; Bhella, 1988; Decoteau et al., 1988). Kasperbauer and Hunt (1987) reported that soil and surface residue color influenced the spectral balance of canopy light and affected the height of cowpea. Recently, Decoteau et al. (1989) reported that tomato plants grown over red mulch produced greater yield than those grown over traditional black and white mulches. Hunt et al. (1985, 1989) found that soil or mulch surface color and the associated differences in spectral balance of reflected light affected soybean nodulation. The objective of this study was to evaluate the influence of different colored mulches on the yield of field-grown cowpea.

MATERIALS AND METHODS

Studies were conducted on a Norfolk loamy sand at the Coastal Plains Soil and Water Conservation Research Center, Florence, SC, in 1984, 1987, and 1988. Plots were 4.5-m long by 3-m wide and were fertilized with 15, 84, and 1100 kg ha^{-1} of P, K, and dolomitic lime, respectively. Prior to planting, trifluralin (α,α,α-trifluoro-2,6-dinitro-*N,N*-dipropyl-*P*-toluidine) was applied at 0.7 L ha^{-1} and incorporated into the soil for weed control.

Cowpea cultivars Mississippi Silver and Colossus were planted in rows with 0.75-m spacings with north/south (1984) or east/west orientation (1987); both orientations were used in 1988. Seeds were planted during June or July of all three years. Styrofoam[1] insulation panels (Dow Chemical Co., Midland, MI) were used in 1984, and straw erosion control blankets (S150-North American Green Co., Evansville, IN) were used for mulch in the other years. Mulches were painted red (Ace Paints #159A110, Ace Hardware Corp., Oak Brook, IL), white (Southern Coatings #148-0410, Southern Coatings, Inc., Sumter, SC), or black (Ace Paints #197A105). Painted mulches were placed around the plants at ~10 d after planting. Water was applied as needed by trickle irrigation in 1984 and 1987 and by overhead irrigation in 1988.

Soil temperatures at the 20-mm depth were monitored by use of a Campbell CR7 Datalogger (Campbell Scientific, Logan, UT) and copper-constantan thermocouples. A Li-Cor 1800 spectroradiometer (Li-Cor, Inc., Lincoln, NE) equipped with a 1.5-m fiber optic probe and a remote integral hemispherical light collector (cosine-corrected sensor window) was used to measure reflectance. Spectral composition of upwardly reflected light from the various colored mulches was measured by positioning the probe near the canopy surface. Measurements were made at ~0900 h (daylight time) on clear days shortly after mulches had been placed around the plants and at the late flowering stage of growth. Photon flux densities were measured at 5-nm intervals from 400 to 800 nm. Spectral irradiances at 735 ± 5 and 645 ± 5 nm were used to calculate FR/R ratios because these wavebands are at the action spectrum peaks for FR- and R-absorbing forms of phytochrome, respectively, in green plants (Kasperbauer et al., 1964). The FR/R ratios are expressed relative to incoming sunlight [(FR to R ratio of reflected light)/(FR to R ratio of incoming sunlight)]. Ratio differences from 1.00 are measures of the relative variation of reflected light from incoming sunlight at the time of measurement.

A split-plot design with four replicates was used in 1984, 1987, and 1988a. Mulch color was the main plot, and cultivar was the sub-plot treatment. In 1988b, row direction was the main plot; mulch color was the sub-plot, and cultivar was the sub-sub-plot.

Pod yields were taken from the center 3 m of each row. Data analyses were performed by analysis of variance (SAS Institute, 1985) and differences among means separated by the LSD test.

[1] Mention of trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the USDA or the South Carolina Agric. Exp. Stn. and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

RESULTS AND DISCUSSION

Light Environment

Spectral balance and quantity of photosynthetically active light reflected from surfaces of various mulches were different. White, red, and black mulches reflected > 35, 12, and 3% of incoming PPFD, respectively (Table 1). Red surfaces reflected light more similar to the black surfaces in the 400 to 570 nm range and more similar to the white in the 620 to 800 nm range (Fig. 1). Red mulches reflected light with FR/R ratio means of 1.25 ± 0.05. Black and white mulch surfaces

Table 1. Photosynthetic photon flux density (PPFD) and far-red/red ratios (FR/R) of light reflected from different colored mulches around cowpea in early and late season.

Light characteristics†	Mulch color: Red	White	Black	LSD (0.05)
	Before crop canopy			
PPFD, %	12	48	3	1
FR/R	1.20	0.99	1.05	0.02
	With crop canopy			
PPFD, %	12	36	4	6
FR/R	1.29	1.07	1.10	0.14

† PPFD and FR/R are expressed relative to incoming sunlight at the time of measurement; the FR/R ratio of incoming sunlight is 1.00.

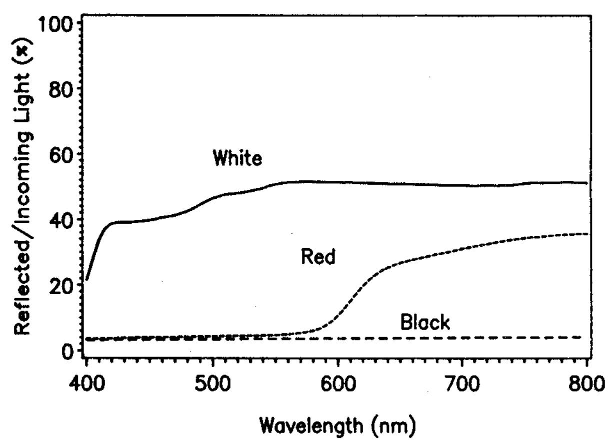

Fig. 1. Spectral distribution of upwardly reflected light above white, red, and black mulch surfaces relative to incoming sunlight (which was considered to be 100% for each measured wavelength). Measurements were taken ~10 cm above the mulch surfaces at 0900 h on a cloudless day ~1 wk after cowpea emergence.

Table 2. Influence of mulch surface color on pod yield of two cowpea cultivars grown on a Norfolk loamy sand.

Mulch color	1984	1987	1988a†	1988b†	Mean
	Mg ha^{-1}				
		Colossus			
Red	6.95	6.34	6.52	7.17	6.75
White	6.49	5.44	6.34	6.97	6.31
Black	6.31	6.03	6.40	6.97	6.43
LSD (0.08)	NS	NS	NS	NS	NS
		Mississippi Silver			
Red	7.14	5.52	6.91	7.33	6.73
White	7.45	5.43	6.37	6.04	6.32
Black	7.05	3.53	5.27	6.57	5.61
LSD (0.08)	NS	1.14	1.32	0.81	0.62
		Mean			
Red	7.05	5.93	6.72	7.25	6.74
White	6.97	5.44	6.36	6.51	6.32
Black	6.69	4.78	5.84	6.77	6.02
LSD (0.08)	NS	NS	NS	NS	0.41

† In 1984, 1987, and 1988a mulch color was the main plot, cultivar the subplot; in 1988b, row direction was the main plot, mulch color was the subplot, and cultivar the sub-subplot.

reflected light with FR/R ratio means of 1.05 ± 0.05. Slightly higher FR/R ratios obtained after establishment of plant canopies were due to reflectance of incoming FR light from the leaf surfaces of neighboring plants (Kasperbauer, 1987). Mean soil temperature differences among mulch colors were <1 °C. Soil temperature differences below the mulches were not sufficient to cause major differences in plant growth and yield, but differences in reflected light spectra were sufficient to cause such variations. Kasperbauer (1988) reported that the FR/R photon ratio acts through the phytochrome system within the plant and influences the distribution of photosynthate.

Plant Response

Since row orientation by mulch color interactions did not significantly affect pod yield in this study, row orientations were pooled for the 1988b statistical analysis and mean presentations. Pod yields were influenced by the different mulch colors ($P = 0.04$) (Table 2). Cultivars were not significantly different ($P = 0.10$). Additionally, neither the color × cultivar nor color × year interactions were significant ($P = 0.10$). Cowpea grown over red mulch had numerically higher pod yields than those grown over white and black mulches in 7 of 8 and 8 of 8 cultivar-site-years, respectively. Cowpea grown over red mulch had the highest 4-site-yr pod yield ($P = 0.08$). Decoteau et al. (1989) reported that marketable yields of tomato also were significantly higher with red mulch than with black or white mulch. The red surface reflected light with a higher FR/R ratio than black or white, but it reflected light that was intermediate to black and white in PPFD. Thus, the higher yield appears to be related to the higher FR/R ratio over the red mulch. Kaul and Kasperbauer (1988) reported higher yield of bush bean plants that received slightly higher FR/R ratios, without a significant change in photosynthetic light.

Colored mulches can influence the microenvironment sufficiently to affect pod yield of cowpea. Beneficial effects of one mulch color compared with others may be influenced by factors such as season or geographic location. A better understanding of light-mediated growth responses should provide a basis for better use of mulches in the production of cowpea.

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